Basic Investigation on Medical Ultrasonic Echo Image Compression by JPEG2000 - Availability of Wavelet Transform and ROI Method -

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Abstract- **Lossy pulse-echo ultrasonic image compression by a JPEG baseline system is permitted by DICOM. In addition to the use of JPEG, use of JPEG2000 will be approved in the near future. The main features of JPEG2000 are use of wavelet transform and ROI (Region of Interest) method. It is expected that wavelet transform is more effective than Fourier transform for ultrasonic echo signal / image processing. Furthermore, ROI method seems to be appropriate compression method of medical images. The purpose of this paper is to investigate the effectiveness of wavelet transform compared with DCT (JPEG) and ROI method for medical ultrasonic echo image compression. The image quality is evaluated by PSNR and the subjective assessment by medical doctors and ultrasonographers. Results reveal that wavelet transform achieves a lower bit rate compared with DCT under the same image quality. In regard to ROI method, it is important that how place of ROI is determined and how much image quality in the other region is reduced.**

***Keywords* – wavelet transform, ultrasonics, pulse-echo image, compression**

I. INTRODUCTION

The trend in medical imaging is increasingly digital. The amount of digital radiological images captured per year in the United States alone is at the order of petabytes, i.e., 10^{15}, and is increasing rapidly every year[1]. The quantities of their imaging data are forcing consideration of compression[1,2,3].

Lossy compression can achieve much higher compression ratio though it doesn't permit the exact recovery of the original image. Storing digital medical images is standardized by the DICOM (Digital Imaging and COmmunications in Medicine) report[1]. It doesn't suggest using lossy algorithms for radiological images. It, however, permits lossy image compression by a JPEG (Joint Photographic Expert Group) baseline system for pulse-echo ultrasonic images due to their poor resolution. In this case, the most important problem is how diagnostic quality is maintained under much higher compression ratio.

On the other hand, JPEG2000 is being established. The use of JPEG2000 will be approved by DICOM in the near future. The main features of JPEG2000 are use of wavelet transform[4] and ROI (Region of Interest) method. It is expected that wavelet transform is more effective method than Fourier transform for ultrasonic echo signal / image processing since traveling of ultrasonic pulse wave in biological media corresponds to translation (shift) of mother wavelet and attenuation of the pulse wave, which depends on frequency, corresponds to dilation (change of scale) of mother wavelet. Being based on this point, wavelet transform has been applied to medical ultrasonic echo signal processing for the purpose of detecting ultrasonic pulse wave from noisy received signal[5]. Furthermore, ROI method, in which image quality in ROI is kept very high but one in the other region is reduced on purpose, seems to be appropriate compression method of medical image since medical doctors pay attention to a part of medical image for diagnosis in most cases of diseases.

The purpose of this paper is to investigate the effectiveness of wavelet transform compared with DCT (Discrete Cosine Transform, which is used in JPEG) and ROI method for medical ultrasonic echo image compression. The image quality is evaluated by PSNR and the subjective assessment. The subjective assessment is carried out by medical doctors and ultrasonographers.

II. COMPRESSION METHODS

A. Comparison between Wavelet Transform and DCT

A comparison between wavelet transform (WT) and DCT is achieved as follows. First, an image is transformed by WT. An obtained wavelet coefficient series is sorted in decreasing order of value in order to determine a threshold. After that, wavelet coefficient is left in a higher rank more than a threshold, and replaced by zero in a lower rank under the threshold. The threshold is determined by the remaining rate, X[%]. That is, a wavelet coefficient in position corresponding to X[%] from the top of the sorted wavelet coefficient series is determined as the threshold. Finally, an image is restored by the renewed wavelet coefficient series. The restored image is justly degraded. The image quality is evaluated by PSNR and the subjective assessment.

In the case of DCT, an image is transformed with 8*8 block DCT based on a JPEG baseline system. Many blocks are transformed and averaged. As a result, 64 coefficients, which reflect characteristics of medical ultrasonic echo image, are obtained. A threshold is determined in a similar way to the case of WT. Restored image is obtained in a similar way, too and compared with one in the case of WT.

B. ROI Method – 1

In this investigation, medical ultrasonic image, which is taken by convex probe, is used. This image (hereafter, it is called convex image.) has some features as follows. Human media are shown in fan-shaped region (see Fig.1 in session III). And image quality in upper area (probe side) is higher than one in the bottom area (the depths of human body). Because intervals of scanning lines of ultrasound transmitted from convex probe spread gradually as ultrasound travels in

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Abstract

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human media. Therefore, the bottom area of convex image is scarcely used for diagnosis.

In ROI method-1, therefore, a half region from the top is set as ROI and the remained half region is divided into three parts along longitudinal direction of image (see Fig.4 in session III). At the lower half area, the lower a part is, the poorer the quality of image is.

The image quality in each part can be changed by JPEG quantization table[6]. Properly speaking, WT (JPEG2000) should be used. However, it does not matter in the sense where the purpose is to evaluate the effectiveness of ROI method. Although every parts use the same JPEG quantization table, quality factors (QF) of each part are different each other. The larger QF is, the poorer image quality becomes. The JPEG quantization table used in this investigation is one optimized for convex image in ref.[7].

In this investigation, it is insignificant to evaluate the image quality by PSNR since ROI has high quality of image and the quality in the other region is degraded on purpose. Therefore, the subjective assessment of the quality of images is very significant.

C.ROI Method – 2

In ROI method-2, a convex image is classified into four parts. They are background (black area), text part and fan-shaped human media region. Fan-shaped region is divided in two regions, ROI and the other region (for example, see Fig.6 in session **3**). A JPEG quantization table for background has 255 in value at all components and one for text part is optimized by statistical method[6]. The optimized table in ref.[7] is used for fan-shaped region. QFs are fixed in 1 in background, text part and ROI. QF in fan-shaped region except ROI is variable. The image quality of this region is made degrade. The limit of degradation is investigated.

III. EXPERIMENTAL RESULTS AND DISCUSSIONS

A. Comparison between WT and DCT

Reference image is shown in Fig.1. The image is kidney image. The resolution is 512*512 and the pixel depth is 8[bits/sample]. In the case of WT, Daubechies' series (N=2) is used as MW and the image is decomposed in three stages as shown in Fig.2.

Table I shows the experimental results. PSNRs in the case of WT are significantly high compared with the case of DCT. Fig.3 shows restored image in the case where the remaining rate is 10[%]. Although block noise characteristic of JPEG images can be recognized in Fig.3(a), the image quality of Fig.3(b) is equivalent to one of reference image. An ultrasonographer's suggestion is the same. As these results, it is shown that WT is more effective compression technique of medical ultrasonic echo image than DCT.

Fig.1. Reference image.

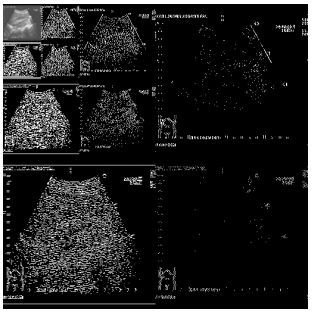


Fig.2. WT of Fig.1. Decomposed in three stages.

(a) Restored image in the case of DCT.

(b) Restored image in the case of WT.

Fig.3. Comparison between DCT and WT. PSNRs are 30.41[dB] and 34.42[dB], respectively.

TABLE I
Comparison of PSNRs[dB] between DCT and WT.

The remaining rate [%]	DCT	WT
25	35.38	46.88
10	30.41	34.42

B. ROI Method – 1

It is shown in Fig.4 that reference image and how the image is classified. The image is liver image and the resolution is 640*480 and the pixel depth is 8[bits/sample]. Region I is ROI and includes focal region of transmitted ultrasonic beam. QFs are decided as 1:1:1:1 (pattern A) , 2:2:2:2 (pattern B) and 1:1.3:1.6:2 (pattern C) in I : II : III : IV, respectively.

Results of the subjective assessment of the quality of images are shown in Table II. This assessment is carried out based on "Recommendation ITU (International Telecommunication Union) -R BT.500-10", as follows.

- more than 5 ultrasonographers and/or medical doctor. They have no information about images.
- 4 types of image are used. Reference and 3 types of test image (in this case, pattern A,B and C).
- Each image is presented 5 times in a session randomly.
- Therefore, a session has 20 images.
- Each image is presented for 15 seconds at intervals of 15 seconds.

- If possible, it is expected that 3 sessions per person are carried out using different images.
- The testers decide whether the quality of each image is good enough for diagnosis.

TABLE II
Results of the subjective assessment for ROI Method-1.

Pattern of image	good	no
Reference	29	0
Pattern A	27	3
Pattern B	3	29
Pattern C	29	2

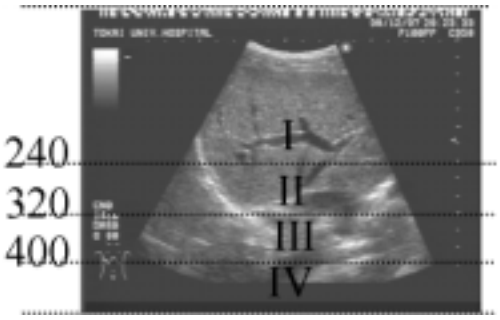


Fig.4. Reference image in ROI method-1.

Although the quality of image in regions II, III and IV of pattern C is degraded and the quality in region IV of pattern B and one of pattern C are the same quality (the same QF) , pattern C is judged good for diagnosis by ultrasonographers. As this result, it is shown that ROI method is very effective compression method for medical image. It is sure that the compression rate of pattern C is better than one of pattern A. Fig.5 shows (a) : pattern A image, (b) : pattern B image and (c) : pattern C image, respectively.

C. ROI Method – 2

Fig.6 shows reference image. ROI is placed in liver region including blood vessel. QF in the fan-shaped region except ROI is set to 1.1, 1.3, 1.5 or 2.0. QF in ROI is fixed in "1". An ultrasonographer's decision is shown in Table III. In spite of the same quality in ROI, it is decided that the images in the cases where QF is 1.3, 1.5 or 2.0 are not good for diagnosis. Of course, the ultrasonographer does not know that the qualities in ROI of these images are the same quality. This result suggests that an impression of the quality in ROI suffers from the quality in regions except ROI, which is degraded. The good result of ROI Method-1 is caused by phased degradation of the quality in regions except ROI. As the result, it is shown that it is important problem that how the quality in regions except ROI is degraded. Restored images are shown in Fig.7.

(a) Restored image of pattern A.

(b) Restored image of pattern B.

(c) Restored image of pattern C.

Fig.5. Restored images in the case of ROI Method – 1. (a) and (c) are good for diagnosis by the subjective assessment. The compression rate of (c), which uses ROI Method, is better than one of (a) obviously.

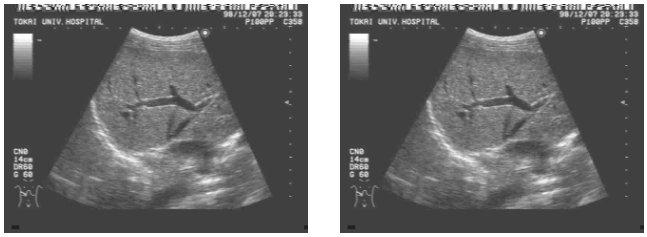
TABLE III
Evaluation by an ultrasonographer for ROI Method-2.

QF in region except ROI	1.1	1.3	1.5	2.0
Good for diagnosis ?	yes	no	no	no

Fig.6. Reference image and place of ROI in ROI Method – 2.

IV. CONCLUSIONS

The main features of JPEG2000 are use of wavelet transform and ROI method. It is expected that wavelet transform is more effective than Fourier transform for ultrasonic echo signal / image processing. Furthermore, ROI method seems to be appropriate compression method of medical images. Therefore, the use of WT and ROI method were investigated for medical ultrasonic echo image compression in this paper.



(a) Restored image (QF : 1.1). (b) Restored image (QF : 1.3).

Fig.7. Restored images in ROI Method – 2. Although the qualities in ROI of these images are the same, (a) is good enough for diagnosis but (b) is not good for diagnosis by decision of ultrasonographer.

Results reveal that wavelet transform achieves higher quality of image compared with DCT under the same amount of data since the wavelet form is very similar to incident pulse waveform. In regard to ROI method, it is shown that ROI method is suitable technique for medical image compression. It is, however, important problem that how the quality in regions except ROI is degraded. Because an impression of the quality in ROI, even if the quality should be very high, suffers from the quality in regions except ROI, which is degraded on purpose.

There still remain other problems to be investigated. For example, coding process should be investigated. In JPEG2000, bit plane coding process is used. The precise subjective assessment of the quality of pictures, finding out the optimum MW for ultrasonic image processing and investigation of the difference of features of echo images caused by shape of probe, scanning method and biological tissue structure are important problems, too. On the other hand, color ultrasonic image such as color Doppler image compression is also important problem.

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